# "On the Geometrical Construction of the Oxygen Absorption Lines Great A, Great B, and $\alpha$ of the Solar Spectrum."

By George Higgs. Communicated by R. T. Glazebrook, F.R.S. Received February 20,—Read March 9, 1893.

In the early part of August, 1890, the photographic work of the normal solar spectrum which I had undertaken had been carried as far as great A, or the limit of visibility in the red, and to $\lambda$ 8350, or beyond $z$, in the invisible regions.

During the two previous months of continuously dull weather, while classifying and comparing results, I was interested, on making a close examination of the head portion of the A line, to find the symmetrical construction, the rhythmical grouping, the harmonic order of sequence, and other characteristics of the B line repeated here in every detail.

These two bands, together with alpha, are composed of a number of doublets or pairs, which approach each other on the more refrangible side with uninterrupted regularity, finally crossing, and at the limiting edges of all three bands the three last pairs overlap each other.

The differences of wave-length between the components of pairs increase in the same order.

These and other properties, which will be referred to, are still more obvious in the trains or flutings.

From its holding an intermediate rank in each of its distinguishing characters I was induced to adopt B as a typical group in a geometrical representation, and to investigate the subject by means of rectangular co-ordinates.

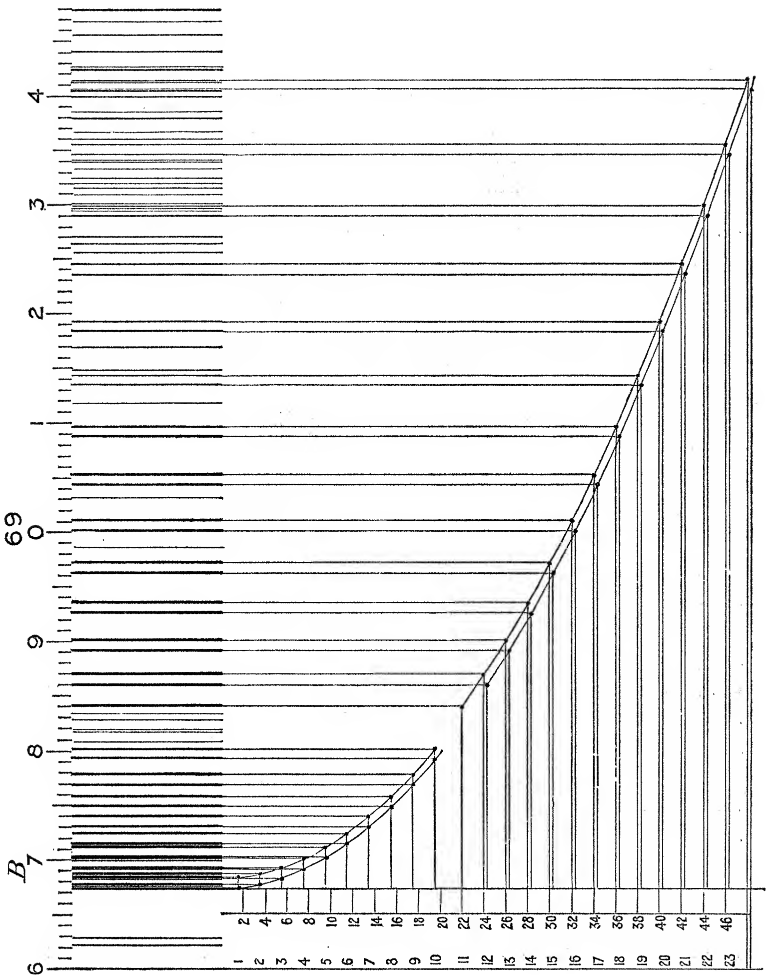
Before a complete analysis could be made out, a micrometer had to be completed. This consisted of a platform, serving as a plate holder, which was made to travel on runners between parallel ways by means of a screw of such a pitch as to move the negative from one division of the scale to the next, for one revolution of the divided plate on the screw head, this latter being divided into 100 parts.

On and over the platform, a microscope is mounted with slide motions at right angles to each other; an index of glass fibre and reflector complete the apparatus.

Over 1000 measurements of nearly 200 lines have been made, 100 of which belong to great A.

In the analysis the axis of $x$ is assumed to occupy a position coincident with, or parallel to, the scale of $1/10^{10}$ m. units, and the positions of the various lines are set off on this scale (see fig. 1) for

FIG. 1.



the group, which is divided into four series. Ordinates are then drawn in the position occupied by each line. The axis of $y$ is divided into a number of equal parts, 1, 2, 3, $n$. Lines parallel to the axis of $x$, drawn from each of these divisions, intersect the respective ordinates. The continuous curve passing through the points of intersection is found to possess all the properties of a parabola.

Three points at least are selected to determine the position of the vertex and value of latus rectum. The distance from the origin along $y$ is also found for an ordinate to the first line of a series.

Now, from the equation to the parabola $y^2 = px$, the formula $\lambda = V + \frac{(n+c)^2}{p}$ is derived, where $V =$ the wave-length in $1/10^{10}$ m. units of a point in the spectrum coinciding with the vertex of the curve; $p$, the latus rectum; $n$, any number of units, reckoning from the origin; $c$, a constant.

In practice a representation more suitable for lantern projection being desirable, two units are taken on $y$ for each line of the series; the equation then becomes $\lambda = V + \frac{(2n+c)^2}{L}$, where $L = 4p$, and $c$ has twice its former value.

The computed places in the tables are derived from the equation in the latter form; the maximum want of agreement between these and the observed positions not exceeding (for $\alpha$ and B) 0·015 tenth-metre.

In the case of A the agreement is not quite so close, the maximum difference being about 0·05 tenth-metre.

It might be supposed that the greater difference arose from uncertainties of observation, caused by the greater haziness and breadth of the lines composing the A group; but it so happens that each component is in itself so much of a double as to show a bright rift in the centre, which facilitates the centralisation in some degree.

The differences referred to are attributable to the fact that the curve for any series in A, B, or $\alpha$ is not rigorously parabolic, but one which cuts the parabola in three points, similar to the curve of sines, cutting a straight line and terminating in the same phase as at the origin. This difference is so extremely minute in B (and in $\alpha$ still less) that it would require a representation more than 10 feet square, or a good sized lantern screen, to show two separate tracings at a point of maximum divergence, assuming the tracings to have but a breadth of 1/100th of an inch.

Following the stronger doublets in the fluting or train of A on the less refrangible side, is a secondary train of thinner, sharply defined, doublets, which, with a solar altitude of about 10°, may be traced on the photographic prints to about the 12th position. This series, which was not previously known to exist, conforms to the same formula, and in the table of wave-lengths is denominated the "Secondary Train of A." This secondary train follows in the wake of the right component of the primary series. In the head, however, similar secondary groups follow in the wake of both right and left components, overlapping and interlacing each other in such a manner that their resolution into series can only be arrived at by deductive processes; the difficulty is increased by the fact that a large number of positions are occupied by the dense lines of the main band.

These two series will be referred to as "Sub-groups" in the head

of A. They are, with two or three exceptions, given in a fragmentary state. At the same time, there is nothing to prevent their hypothetical positions being carried further, except that the greater density of the principal series precludes the possibility of obtaining any check in regard to their conformity.

Generally, a couple of numbers of the head bands are common to two separate series; this arises from their complexity being suggested by the nature of the analysis, and, as a matter of fact, some of these have been observed as doubles by Professor Rowland, of Baltimore.

In all cases of this kind a greater density is observable on the prints, and is doubtless the cause of the extra density of 7608·83, which belongs to two sub-groups; the line 7610·10 is known to be a double, but cannot with safety be measured as such.

Owing to their incompleteness, the elements of the curves for the sub-groups in head of A have not been made out, but a glance at their second differences is sufficient to establish their agreement with the preceding form, since an interval is equal to $d' + (n-1)\, d''$, where $d'$ and $d''$ are first and second differences, and $n$ any interval from the commencement of the series.

*Note.*—Since writing the above I find that Mr. Johnstone Stoney has written a note which was published with a paper by Dr. Huggins on the spectrum of hydrogen, in which he refers to the conditions under which members of a harmonic series might fall near to, but not on, a curve.

Fig. 2 is an enlargement of part of A

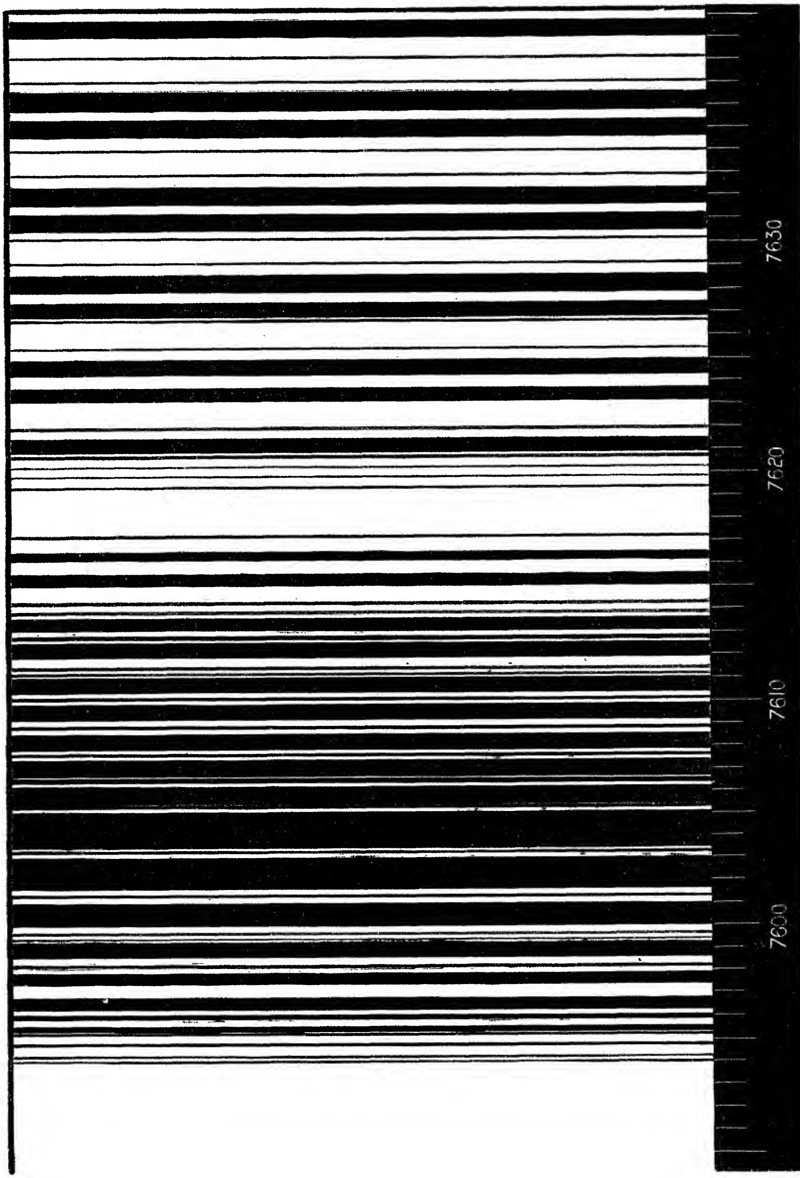



Fig. 2.

## Head of the Alpha Line.

| | 1st Series. | | 2nd Series. | |
|---|---|---|---|---|
| | Computed. | Measured. | Measured. | Computed. |
| 1. | 6276·792 | 6276·798 | 6277·652 | 6277·644 |
| 2. | 77·020 | 77·013 | 77·845 | 77·856 |
| | | | 78·190 | |
| 3. | 77·514 | 77·518 | 78·280 | 78·335 |
| | | 78·190 | 78·370 | |
| 4. | 78·275 | 78·280 | 79·084 | 79·082 |
| | | 78·370 | | |
| 5. | 79·302 | 79·302 | 80·095 | 80·095 |
| 6. | 80·596 | 80·594 | 81·374 | 81·375 |
| 7. | 82·156 | 82·148 | 82·924 | 82·922 |
| 8. | 83·983 | 83·990 | 84·735 | 84·736 |
| | V = 6276·775 | | V = 6277·632 | |
| | L = 30·019 | | L = 29·964 | |
| | $c$ = −1·29 | | $c$ = −1·41 | |

## Train of the Alpha Line.

| | 1st Series. | | 2nd Series. | |
|---|---|---|---|---|
| | Computed. | Measured. | Measured. | Computed. |
| 9. | .. | .. | 6287·935 | 6287·942 |
| 10. | 6289·596 | 6289·591 | 90·411 | 90·408 |
| 11. | 92·344 | 92·350 | 93·140 | 93·141 |
| 12. | 95·356 | 95·360 | 96·141 | 96·140 |
| 13. | 98·634 | 98·640 | 99·416 | 99·407 |
| 14. | 6302·176 | 6302·178 | 6302·941 | 6302·940 |
| 15. | 05·984 | 05·980 | 06·741 | 06·740 |
| 16. | 10·056 | 10·040 | 10·795 | 10·806 |
| 17. | 14·394 | 14·399 | 15·135 | 15·140 |
| 18. | 18·996 | 19·008 | 19·750 | 19·740 |
| | V = 6276·693 | | V = 6277·746 | |
| | L = 30·19 | | L = 29·985 | |
| | $c$ = −0·263 | | $c$ = −0·515 | |

Head of Great B.

| | 1st Series. | | 2nd Series. | |
|---|---|---|---|---|
| | Computed. | Measured. | Measured. | Computed. |
| 1. | 6867·464 | 6867·455 | 6868·457 | 6868·464 |
| 2. | 67·776 | 67·788 | 68·782 | 68·771 |
| 3. | 68·338 | 68·337 | 69·330 | 69·326 |
| 4. | 69·150 | 69·148 | 70·130 | 70·130 |
| 5. | 70·212 | 70·220 | 71·180 | 71·182 |
| 6. | 71·523 | 71·530 | 72·485 | 72·484 |
| 7. | 73·084 | 73·080 | 74·039 | 74·033 |
| 8. | 74·895 | 74·892 | 75·834 | 75·831 |
| 9. | 76·955 | 76·950 | 77·879 | 77·877 |
| 10. | 79·266 | 79·274 | 80·170 | 80·172 |
| | V = 6867·394<br>L = 32·03<br>$c$ = −0·5 | | V = 6868·397<br>L = 32·194<br>$c$ = −0·53 | |

Train of Great B.

| | 1st Series. | | 2nd Series. | |
|---|---|---|---|---|
| | Computed. | Measured. | Measured. | Computed. |
| 11. | .. | .. | 6884·077 | 6884·090 |
| 12. | 6886·012 | 6886·000 | 86·998 | 86·990 |
| 13. | 89·181 | 89·182 | 90·140 | 90·142 |
| 14. | 92·601 | 92·615 | 93·560 | 93·545 |
| 15. | 96·271 | 96·277 | 97·200 | 97·201 |
| 16. | 6900·192 | 6900·193 | 6901·120 | 6901·108 |
| 17. | 04·364 | 04·368 | 05·264 | 05·267 |
| 18. | 08·786 | 08·786 | 09·680 | 09·678 |
| 19. | 13·458 | 13·444 | 14·334 | 14·340 |
| 20. | 18·382 | 18·367 | 19·245 | 19·255 |
| 21. | 23·555 | 23·545 | 24·412 | 24·421 |
| 22. | 28·980 | 28·980 | 29·840 | 29·839 |
| 23. | 34·655 | 34·662 | 35·518 | 35·509 |
| 24. | 40·580 | 40·580 | 41·430 | 41·431 |
| | V = 6867·529<br>L = 31·922<br>$c$ = +0·29 | | V = 6868·812<br>L = 31·767<br>$c$ = +0·03 | |

## Head of Great A.

| | 1st Series. | | 2nd Series. | |
|---|---|---|---|---|
| | Computed. | Measured. | Measured. | Computed. |
| 1. | 7593·980 | 7593·98 | 7595·26 | 7595·260 |
| 2. | 94·276 | 94·28 | 95·42<br>95·54<br>95·66 | 95·543 |
| 3. | 94·796 | 94·79 | 96·05 | 96·050 |
| 4. | 95·540 | 95·42<br>95·54<br>95·66 | 96·78 | 96·781 |
| 5. | 96·508 | 96·49 | 97·73 | 97·736 |
| 6. | 97·700 | 97·69 | 98·90 | 98·915 |
| 7. | 99·116 | 99·12 | 7600·29 | 7600·318 |
| 8. | 7600·756 | 7600·80 | 01·96 | 01·945 |
| 9. | 02·620 | 02·64 | 03·77 | 03·796 |
| 10. | 04·708 | 04·74 | 05·90 | 05·871 |
| 11. | 07·020 | 07·03 | 08·21 | 08·170 |
| 12. | 09·556 | 09·54 | 10·71 | 10·693 |
| 13. | 12·316 | 12·31 | 13·44 | 13·440 |
| 14. | 15·300 | 15·30 | 16·39 | 16·411 |

1st Series: $V = 7593·904$, $L = 35·714$, $c = -0·357$

2nd Series: $V = 7595·195$, $L = 35·715$, $c = -0·473$

## Train of Great A.

| | 1st Series. | | 2nd Series. | |
|---|---|---|---|---|
| | Computed. | Measured. | Measured. | Computed. |
| 15. | .. | .. | 7621·260 | 7621·299 |
| 16. | 7623·590 | 7623·535 | 24·765 | 24·772 |
| 17. | 27·310 | 27·310 | 28·480 | 28·480 |
| 18. | 31·255 | 31·275 | 32·445 | 32·413 |
| 19. | 35·425 | 35·460 | 36·59 | 36·571 |
| 20. | 39·820 | 39·840 | 40·97 | 40·954 |
| 21. | 44·440 | 44·470 | 45·57 | 45·562 |
| 22. | 49·285 | 49·305 | 50·39 | 50·395 |
| 23. | 54·355 | 54·360 | 55·448 | 55·453 |
| 24. | 59·650 | 59·615 | 60·715 | 60·736 |
| 25. | 65·170 | 65·148 | 66·218 | 66·244 |
| 26. | 70·915 | 70·880 | 71·945 | 71·977 |
| 27. | 76·885 | 76·840 | 77·89 | 77·935 |
| 28. | 83·080 | 83·025 | 84·075 | 84·118 |
| 29. | 89·500 | 89·450 | 90·49 | 90·526 |
| 30. | 96·145 | 96·105 | 97·13 | 97·159 |
| 31. | 7703·015 | 7703·020 | 7704·02 | 04·017 |
| 32. | 10·110 | 10·160 | 11·16 | 11·100 |

1st Series: $V = 7594·669$, $L = 35·556$, $c = +0·067$

2nd Series: $V = 7596·044$, $L = 35·556$, $c = -0·04$

Secondary Train of Great A.

| 1st Series. | | 2nd Series. | |
|---|---|---|---|
| Computed. | Measured. | Measured. | Computed. |
| 15. 7622·076 | 7622·06 | .. | 7623·290 |
| 16. 25·613 | 25·62 | 7626·79 | 26·790 |
| 17. 29·356 | 29·36 | 30·50 | 30·502 |
| 18. 33·305 | 39·29 | 34·42 | 34·426 |
| 19. 37·460 | 37·46 | 38·57 | 38·560 |
| 20. 41·821 | 41·81 | 42·91 | 42·910 |
| 21. 46·388 | 46·36 | 47·46 | 47·470 |
| 22. 51·161 | 51·19 | 52·24 | 52·242 |
| 23. 56·140 | 56·14 | 57·23 | 57·226 |
| V = 7593·4535<br>L = 38·835<br>$c$ = +3·34 | | V = 7596·122<br>L = 37·736<br>$c$ = +2·019 | |

Sub-group in Head of A following the 1st Series. — Fragment of Sub-group in Head of A following the 2nd Series.

| Measurements only. | | Measurements only. | |
|---|---|---|---|
| Sub-series No. 1. | Sub-series No. 2. | Sub-series No. 3. | Sub-series No. 4. |
| 5. 7597·00 | 7598·20* | | |
| 6. 98·29 | 99·45 | | |
| 7. 99·74 | 7600·90* | | |
| 8. 7601·42 | 02·57* | | |
| 9. 03·25 | 04·40 | | |
| 10. 05·36 | 06·48 | 10. 7606·48 | |
| 11. 07·65 | 08·83 | 11. 08·83 | 7610·10$d$ |
| 12. 10·10$d$ | 11·28 | 12. 11·45 | |
| 13. 12·84 | 13·98 | 13. 14·28 | |
| 14. 15·78 | .. | 14. 17·25 ? | |

The numbers marked with an * are hypothetical positions.

FIG. 2.